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SIMULATION OF SHOCK LOADING IN SATURATED GEOLOGIC MATERIALS

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ABSTRACT- The effective stress model is used to model the stress-strain, volumetric, and strength behavior in saturated materials under shock loading. The effective stress concept provides a predictive model of the behavior of wet porous materials based on the dry material properties. An effective stress model that allows for arbitrary fluid and solid equations of state and varying levels of saturation is incorporated into an adaptive mesh refinement (AMR) Eulerian shock physics hydrocode. Good agreement is found between simulation results and experimental data for saturated materials, even at moderately high pressures.

INTRODUCTION: The effective stress model has been used effectively to model the behavior of a variety of porous media including soils, concrete, and rock. The formulation due to Terzaghi (Jaeger and Cook [1976]) defines the effective pressure, P_{eff}, as

$$P_{eff} = P - P_{fluid} \tag{1}$$

where P is the total pressure and P_{fluid} is the fluid pressure in the pores. The effective stress is used rather than total pressure to determine stress-strain and strength behavior. Terzaghi's principle has been shown to work relatively well for most geotechnical applications, though significant deviations have been observed under pressures in excess of 100 MPa (Lade and de Boer [1997]).

PROCEDURES, RESULTS, AND DISCUSSION: Simulations of both dry and saturated materials were conducted using an Eulerian adaptive mesh refinement (AMR) hydrocode developed for shock loading of geologic materials. The effective stress concept was implemented such that saturated models can be trivially generated from the corresponding dry material models by providing a fluid equation of state. This implementation treats both fully and partially saturated materials and allows the use of arbitrary equations of state (from analytical equations, tabular data, or run-time databases) to be used for both the solid and the pore fluid; this is particularly useful at the high pressures associated with shock loading. In addition to implementing Eqn. 1 for pressure-dependent material response, the pore compaction behavior of the saturated material was determined by combining the response of the dry material with the behavior at solid-fluid equilibrium. A hyperelastic constitutive model incorporating strength, poro-elasticity, bulking, shear-enhanced compaction and distortional damage was developed for limestone (Lomov and Vorobiev [2004]). This model was calibrated to spherical wave data for dry limestone (Fig. 1). The experimental data were collected by SRI International (Gefken and Florence [1993]); the test consisted of a 3/8-g, 1.0-cmdiameter pentaerythritol tetranitrate charge in 16% porous Indiana Salem limestone. Simulations using the corresponding saturated model were then compared to spherical wave data for fully saturated limestone (Fig. 2). The peak pressure is the saturated test was well in excess of 100 MPa. Despite the higher pressures, good agreement was found using the Terzaghi effective stress concept.

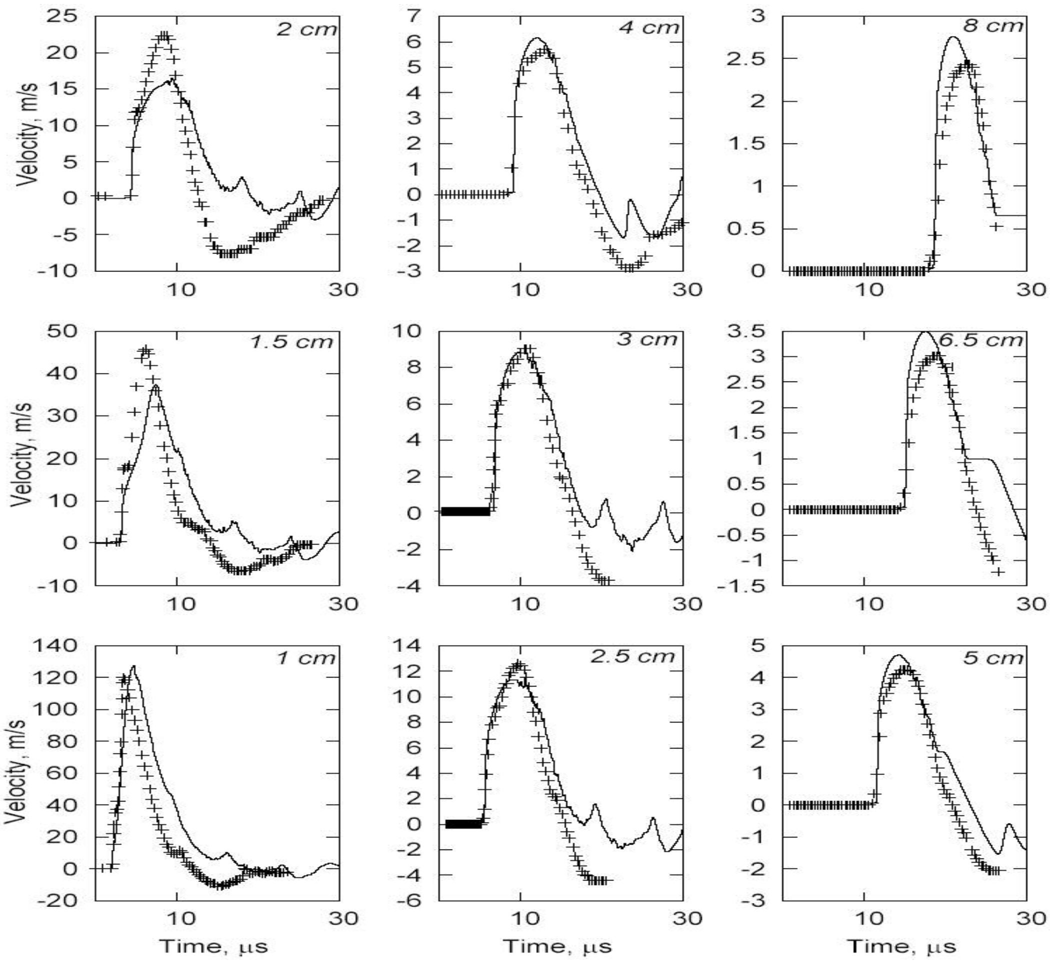

Figure 1. Comparison of velocity waveforms for dry limestone at varying distances from the explosive charge; experimental data (+) and simulation results (—). Model parameters were calibrated to this dataset.

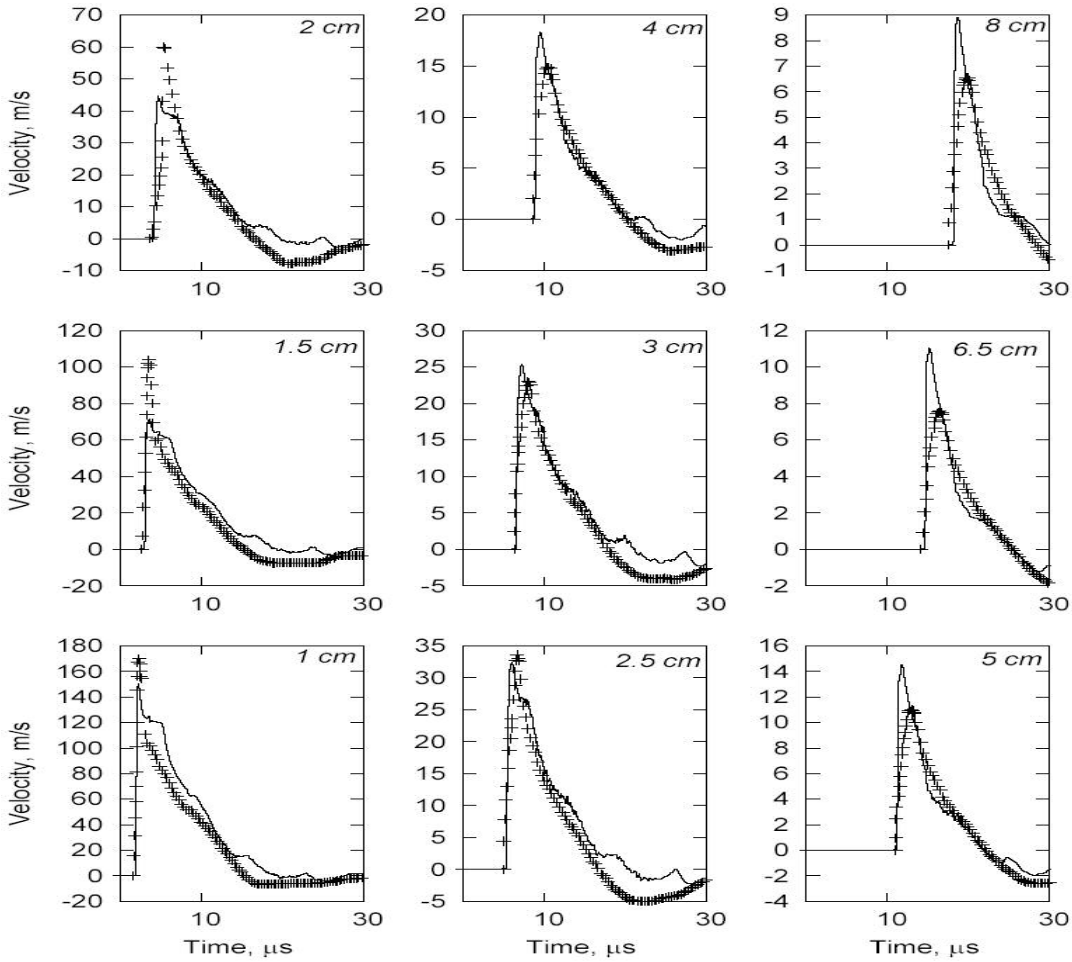

Figure 2. Comparison of velocity waveforms for saturated limestone at varying distances from the explosive charge; experimental data (+) and simulation results (—).

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